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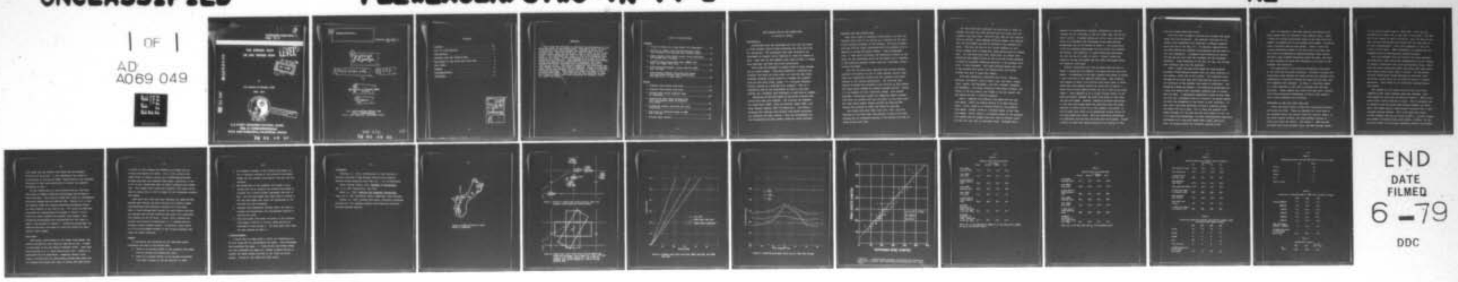

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THE SURFACE WIND ON AND AROUND GUAM

by

LTJG DONALD W. McCANN, USNR

JUNE 1974

U.S. FLEET WEATHER CENTRAL GUAM
BOX 12 COMNAVMARIANAS
F.P.O. SAN FRANCISCO, CALIFORNIA 96630

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CONTENTS

ABSTRACT

This study was designed to correlate the differences in the observed winds on and around Guam. From three years of data correlations were found between the gradient wind and the surface wind. The wind speed over land at 0000Z is 58% of the gradient wind speed and at 1200Z is 36% of the gradient wind speed. The wind speed over water is 73% of the gradient wind speed at all times. These percentages do not vary with the gradient wind direction. The gradient wind direction averages nearly the same as the surface wind direction, but large standard deviations indicate that considerable backing or veering can occur. The diurnal changes of the wind speed over land depend on where the wind is observed. Naval Air Station, Agana, shows the greatest diurnal changes of Guam's three wind recording stations. Wind gusts over water are equal to the gradient wind speed. Gust factors for land stations on Guam are slightly higher than those predicted by Atkinson (1974) for gusts over water.

LIST OF ILLUSTRATIONS

Figures

Tables

THE SURFACE WIND ON AND AROUND GUAM

by Donald W. McCann

INTRODUCTION

Considerable myth has developed over the last few years at Fleet Weather Central Guam concerning the local wind and its variations. The techniques that each forecaster has developed for himself are as numerous as there are shades of grey. Some look at the gradient wind, some at what is coming from upstream, and some just plain persistence.

This study was designed to dispell some of those schemes and to verify others. Data were gathered to correlate the gradient wind with the local wind over land and over water. Findings indicate a high correlation between the gradient wind and the local winds, suggesting a forecast technique heavily relying on a gradient wind forecast. This is a comforting note to the forecasters on Guam in that most already use a gradient wind technique in some form or another.

Variations of the wind speed at the three stations that record wind were also studied. The stations are Andersen Air Force Base (AAFB), Naval Air Station, Agana (NAS), and Fleet Weather Central (FWC) on Nimitz Hill. See Figure 1. Findings here indicate that diurnal wind speed variations are different for each station. This has consequences for the forecasters who must predict winds for these stations.

GRADIENT WIND AND SURFACE WIND

Many early works in dynamical meteorology show that the gradient wind (3000 ft or 1000 m) is a function of the associated pressure gradient at the surface. The local surface wind may then be highly correlated with the gradient wind in absence of strong frictional forces. Guam's topography (Fig. 1) does cause frictional and funnelling effects on the wind, but the frictional force can be shown to be a function of the pressure gradient across Guam and, therefore, statistically derivable.

Data for the study were obtained from plotted surface/gradient wind charts on file at Fleet Weather Central Guam. These are handplotted charts with the gradient wind superimposed on the surface observation. All land and ship reports received were plotted in the vicinity of Guam except for those which crowded the reports already plotted. Figure 2 is an example of such a plotting scheme. This scheme provided a convenient format for comparing Guam's gradient wind with its surface wind and the ships' in the local area. The land report almost always plotted for Guam was NAS. Charts were plotted at 0000Z and 1200Z for each day.

The charts used were those from 1971, 1972, and 1973. Portions of the 1200Z data from January to April 1971 were missing due to infrequent manning of the plotter's billet at night during that time.

The data were then tabulated for each chart in order to compare the wind over land and the wind over water with the gradient wind over Guam. The wind over land was the reported wind as plotted. From standard plotting format, one realizes that the wind speed can only be plotted to the nearest five knots. This was not felt to be a great drawback in that using a sample size of about 800, these errors tend to average zero. For the wind over water (ship wind) all ships' wind directions and speeds within an 180 nm by 480 nm box centered on Guam and oriented lengthwise parallel to the gradient wind (Fig. 3) were averaged. Once again plotted speeds were only to the nearest five knots, but these errors also should average zero with a large data sample.

Data were seasonally classified into winter (January, February, and March), spring (April, May, and June), summer (July, August, and September), and fall (October, November, and December). For those unfamiliar with Guam's climate, the winter is the dry season; the summer is the wet season, and the spring and fall transition seasons.

Table 1 compares the gradient wind speed and the land wind speed. There are several points to be made from the table. First, there is no diurnal effect in the gradient wind speed. Second, there is a diurnal effect of the land wind speed. Third, there is a seasonal effect in the gradient wind speed with the summer being the time of lightest winds and the fall the time of strongest winds. Although there

appears to be substantial seasonal difference in the percentage for all land data is 58% for 0000Z (day) and 36% for 1200Z (night). Standard deviations of the land wind speed about the predicted land wind speed using these average percentages are at the bottom of Table 1. The predictions using the seasonal percentages are well within the standard deviations, and therefore, a single predicting percentage for day and one for night is valid. Figure 4 shows the graph of the day wind speed and the night wind speed versus the gradient wind speed.

Several conclusions can also be drawn from the data in Table 2 concerning the gradient wind speed and the ship wind speed. (Differences of the mean gradient wind speed in Tables 1 and 2 are due to the sampling techniques. Mean gradient wind speeds in Table 2 are derived from those cases in which there were ship reports within the given box in Figure 3. There were no ship reports within the box in 46% of the total cases.) There appears to be a slight diurnal effect in the ship wind speed, whereby the night wind speed is less than the day wind speed. However, computing standard deviations of the ship wind speed about the predicted ship wind speed similiar to above using 73% of the gradient wind speed, it can be shown that there is no significant diurnal effect in the wind speed over water. Thus one predicting percentage is sufficient for both day and night ship wind speeds. Figure 4 shows the ship wind speed prediction line similar to the

land wind speed prediction lines.

Data were then divided to see how the surface wind speed might vary with direction. The gradient wind data for all seasons were classified into quadrants, northeast quadrant being 360 deg to 090 deg, etc. No seasonal classification was made because the predicting percentages derived above do not vary seasonally. A gradient wind direction of exactly 090 deg was put into both the northeast and the southeast quadrants. Wind directions of 180 deg, 270 deg, and 360 deg were similarly put into two quadrants.

Table 3 shows the mean wind speeds for each quadrant. Northeast winds average stronger than any other direction at the gradient level and at the surface. The predicting percentages do not vary much from those derived earlier, hence the direction of the gradient wind makes no difference. One exception stands out however. The predicting percentage for a ship wind speed from a northwest gradient wind is higher than the mean. A speculative explanation might be that Guam can only get a northwest wind as a tropical low passes nearby, and thus the atmosphere at low levels is more turbulent. To test this, data were extracted in which a tropical cyclone was within 300 nm of Guam. For 20 cases the gradient wind speed averaged 24.5 kts and the ship wind speed 17.3 kts, or a 71% predicting percentage, not much difference from predicting percentage for a ship wind speed under normal conditions. Thus, an anomaly exists for northwest gradient winds.

Also of interest is how much vertical directional wind shear occurs from the surface to the gradient level. Table 4 shows the average directional shear of the ship wind with respect to seasons and to the gradient wind speed. A positive number indicates veering with height. Table 4 shows the average directional shear of the ship wind to be less than what would be predicted by standard boundary layer theory; and with large standard deviations about the mean, one might as well consider the ship wind direction to be equal to the gradient wind direction.

The computation of the vertical directional wind shear of the land wind was done indirectly. Instead of finding the directional shear between the land wind and the gradient wind, differences in direction between the land wind and ship wind were computed then averaged. In Table 5 a positive number is a land direction to the left or greater than the ship direction. These numbers also tend to be near zero, indicating little directional difference in land or ship reports with a given gradient wind direction.

VARIATIONS OF THE LOCAL WIND OVER LAND

There are three places on Guam that continuously measure and record the wind. These are Andersen Air Force Base at the northern end of the island, Naval Air Station, Agana, in the north central portion, and Fleet Weather Central on Nimitz Hill near the center. See Figure 1. AAFB and FWC provided their wind recorder rolls, and NAS provided copies

of its hourly airways reports (WBAN-10A). There are two anemometers at AAFB, one on each end of the runway. The east end of the runway is near a cliffline. Only the data at the west end was used because the author felt the east data to be less representative. NAS's wind equipment is near the center of the runway. FWC's anemometer is located atop the Commander Naval Forces Marianas Islands Building.

Data from December 1973 and January 1974 were analyzed. Although short, this period was representative of the variety of synoptic conditions that occur year-round on Guam. There were the usual trade wind surges that occur when large Asian high centers move across Japan in winter. In mid-January Tropical Storm Wanda formed southwest of Guam and, after recurving, passed about 150 nm north of Guam as a tropical depression. Thus winds of all directions occurred during this period.

Wind speeds for all three stations every four hours commencing 0000 local standard time were compared. Mean wind speeds for each time are shown in Table 6. AAFB's wind speed varies little from day to night. This is probably due to exposure near the ocean where heating effects are least. NAS's wind speed shows a large diurnal variation due to much stronger heating effects. FWC's wind speed also shows diurnal changes, but not as strong as NAS's. The FWC average wind speed is stronger than either AAFB's or NAS's. At the bottom of Table 6 is the mean difference between the 1200LST

wind speed and the 0000LST wind speed and the standard deviation of this mean. A null hypothesis test shows no significance of the mean at AAFB, significance to one standard deviation at FWC, and significance to almost two standard deviations at NAS.

As was stated early in the previous section, land wind data used to compute predicting percentages were primarily those from NAS. This section stated that there is considerable variation between NAS and AAFB and FWC. Figure 5 is a crude but helpful guide for finding predicting percentage values for each station at any time of day. The values for NAS were calculated by interpolating the speeds in Table 6 to get 0000Z and 1200Z (1000LST and 2200LST) wind speeds. Then predicting percentages were extrapolated for the times in Table 6 and plotted in Figure 5. Predicting percentages for AAFB and FWC were calculated by using the ratios for their speed to NAS's speed.

WIND GUSTS

Wind gusts, particularly at the higher wind speeds, can create problems for both those on land and at sea. A study of wind gusts at sea was done by Atkinson (1974). Gust data were provided by U. S. Navy ships during 1973. Figure 6 is reprinted with his permission. Comparing Figure 6 with Figure 4 yields that the relationship between peak gusts and the surface wind speed over water is nearly the same quanti-

tatively as that between the gradient wind speed and the surface wind speed over water. For a given surface wind speed there is almost a one-to-one correspondence between between peak gust and gradient wind speed, especially in the 10 to 40 knot range where most of Guam's gradient wind speeds fall. This means that a peak gust forecast over water can be made by saying that it will be equal to the forecasted gradient wind speed.

Gust data over land were only available for AAFB and FWC. Average gust factors for both stations are slightly higher than predicted from Atkinson's equation for over water. Table 7 gives average gust factors for each station and what the average gust factors would be over water for a sustained wind between 10 and 19 knots. Cooley (1974) studied gust factors for stations in Washington, D. C. Weather Service Forecast Office forecast region. He derived a gust factor of 1.6 for wind speeds between 10 and 19 knots greater than those for Guam's stations.

SUMMARY

In conclusion the following are the important points concerning the wind on and around Guam:

1. There is no diurnal effect in the gradient wind speed and the surface wind speed over water.
2. There is a diurnal effect in the surface wind speed over land, largest at NAS and smallest at AAFB.

3. The seasonal changes in the surface wind speed are due to seasonal changes in the gradient wind speed. Summer has the weakest wind speeds, and fall has the greatest.

4. The percentage of the gradient wind speed a forecaster must use to predict the surface wind speed is constant for a given surface topography and time of day. For the wind speed over land refer to Figure 5. For the wind speed over water the percentage is 73% and does not vary diurnally.

5. Gradient wind directions average nearly the same as surface wind directions, but considerable backing or veering can occur.

6. Peak wind gusts over water are equal to the gradient wind speed in the 10 to 40 knot range and can be obtained by using Figure 6. For peak gusts over land, use gust factors in Table 7.

ACKNOWLEDGEMENTS

I would like to thank Bruce A. Clark for allowing me to do this study and for proofreading the paper. Scott Sandgathe also proofread the paper. J. Frank Pratte and Gordon Safely not only proofread the paper but offered valuable advice to correct the badly worded portions in the rough and final drafts. Cecilia M. Ogo typed the final draft.

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Brunt, D., 1952, Physical and Dynamical Meteorology, Chap. IX, p. 190, University Press, Cambridge, Great Britain.

Cooley, D., 1974, Surface Wind Gusts, Technical Procedures Bulletin No. 114, Weather Analysis and Prediction Division, National Weather Service.

Figure 1. Island of Guam with rough sketch of topography.

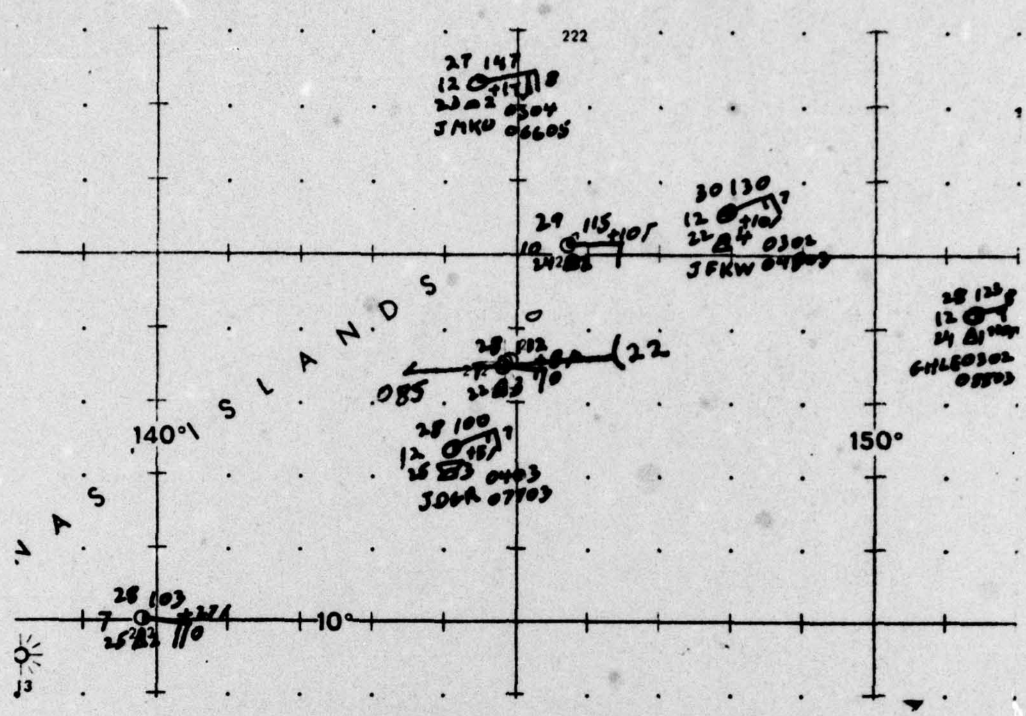

Figure 2. Portion of sample hand plotted synoptic chart with gradient wind plotted over surface report.

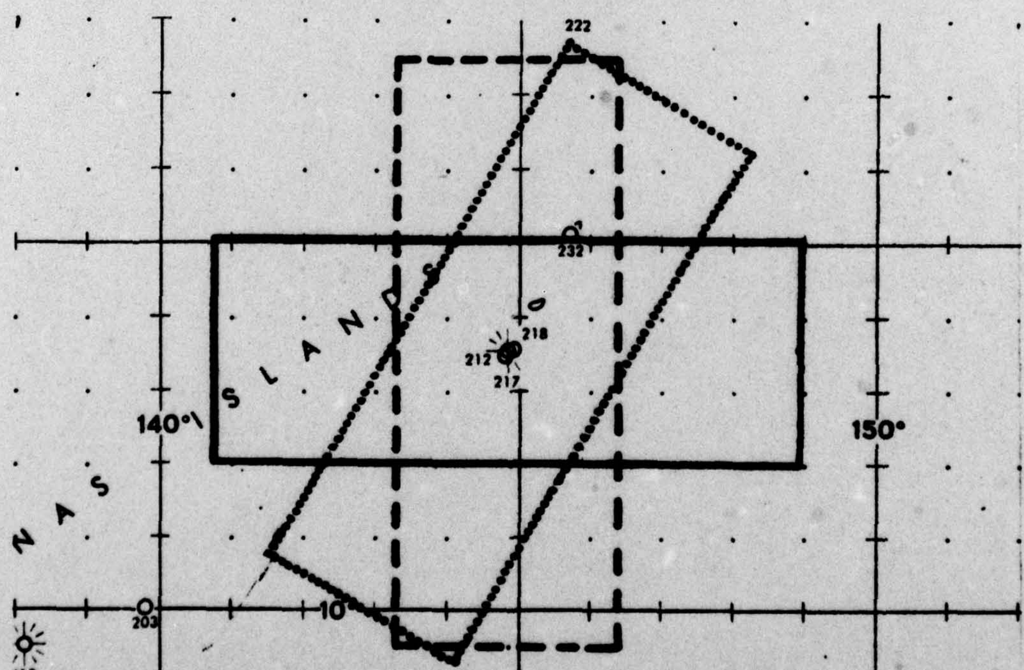

Figure 3. Sample boxes within which ship's wind directions and speeds were averaged. Solid example for a 090 or 270 deg gradient wind. Dashed example for a 180 or 360 deg gradient wind. Dotted example for a 030 or 210 deg gradient wind.

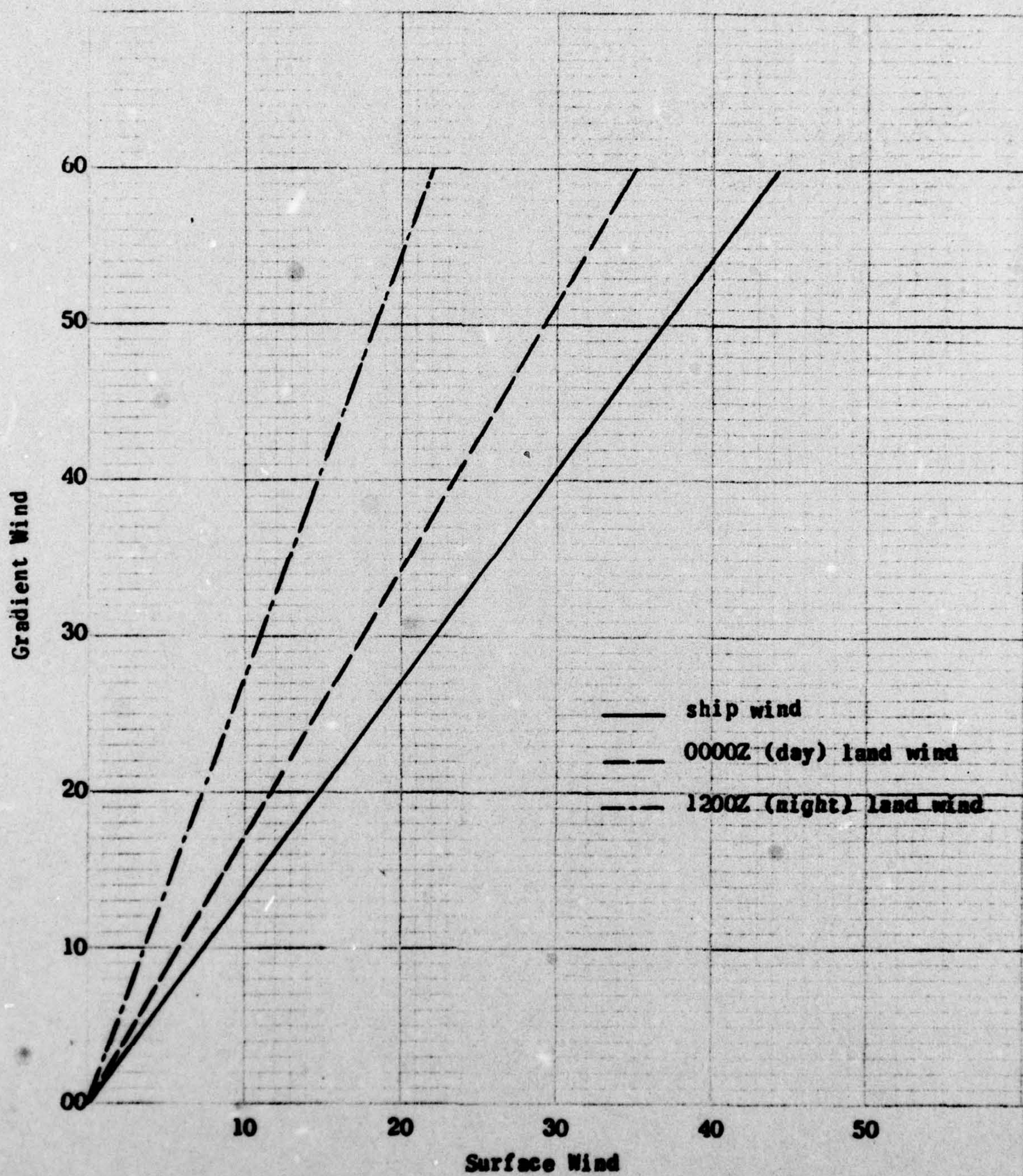

Figure 4. Gradient wind versus ship wind, 0000Z land wind, and 1200Z land wind.

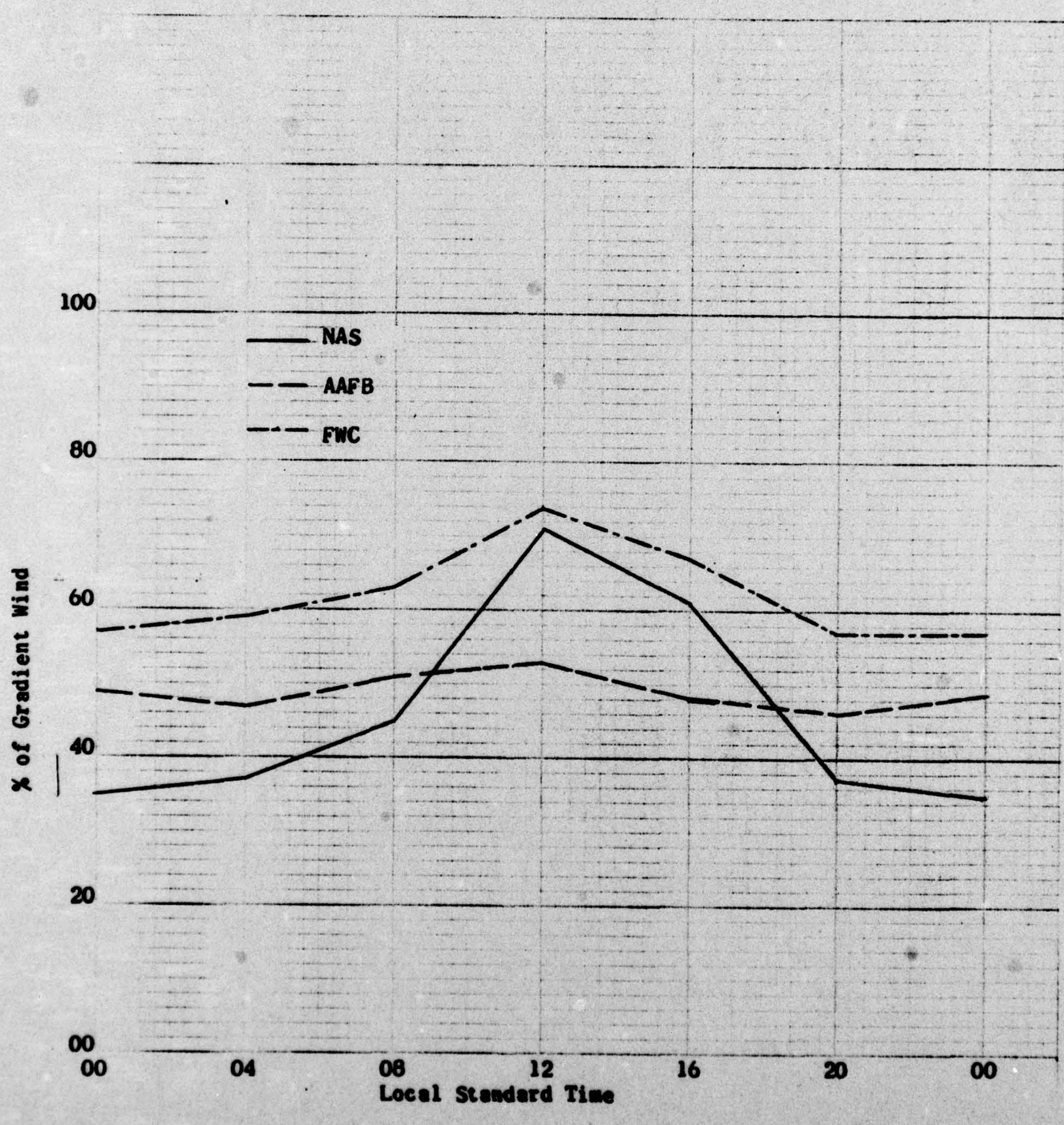

Figure 5. Predicting percentage versus time for AAFB, NAS, and FWC.

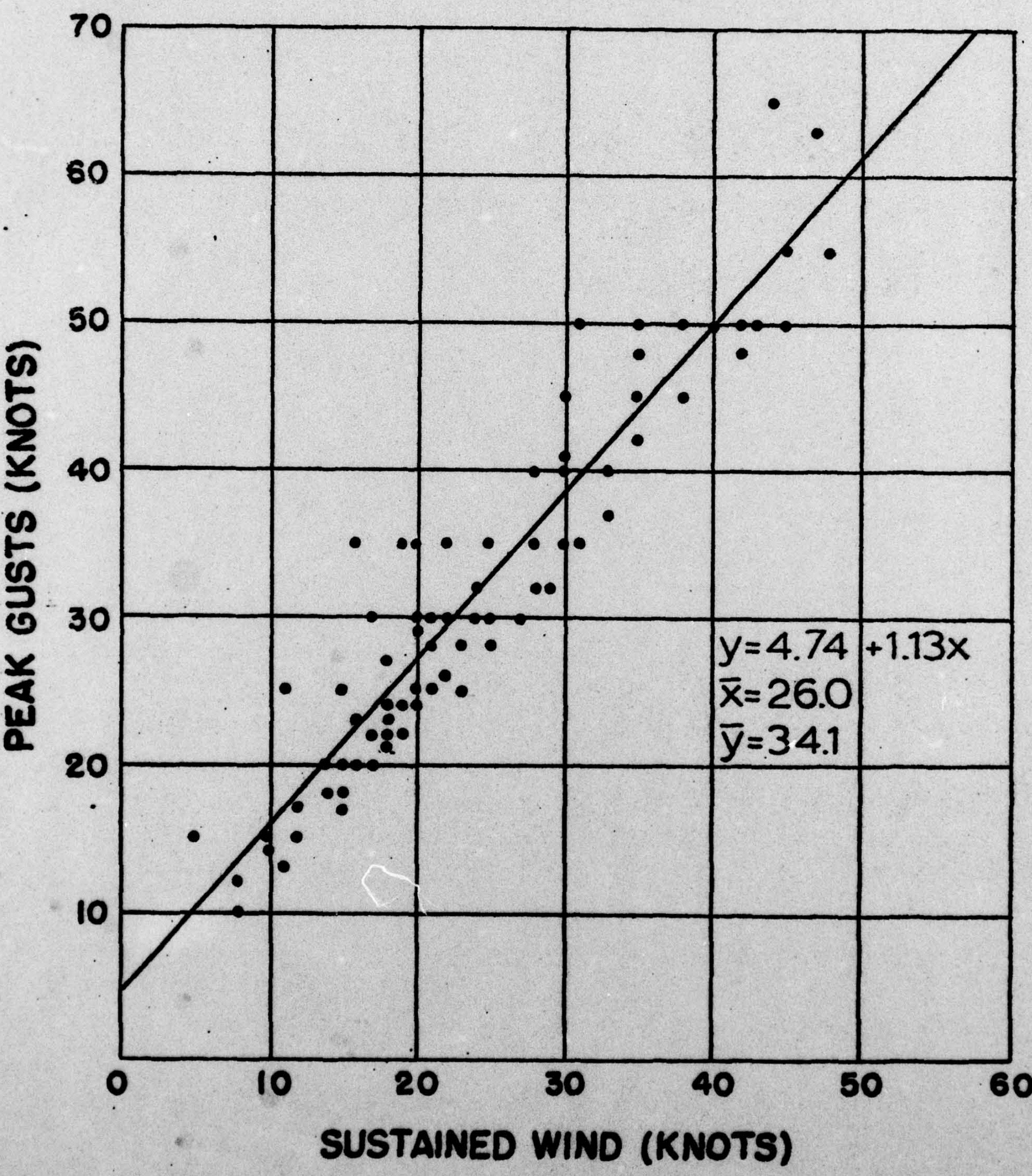

Figure 6 Relationship between sustained wind speed and peak gusts derived from observations provided by U.S. Navy ships.

TABLE 1

Gradient Wind Versus Land Wind
(in knots)

	Winter	Spring	Summer	Fall
Mean 0000Z gradient wind	19.6	17.8	15.4	20.6
Mean 0000Z land wind	11.9	12.0	8.2	10.2
% land wind to 0000Z gradient wind	61%	67%	53%	50%
Mean 1200Z gradient wind	20.0	18.2	14.7	20.6
Mean 1200Z land wind	7.0	8.3	4.7	6.4
% land wind to 1200Z gradient wind	35%	46%	32%	31%
Standard deviation of 0000Z land wind using $w_d = .58w_g$	3.8	3.7	3.8	3.6
Standard deviation of 1200Z land wind using $w_n = .36w_g$	2.9	2.9	2.8	2.9

(Note: w_d is the land wind at 0000Z, w_n is the land wind at 1200Z, and w_g is the gradient wind.)

TABLE 2

Gradient Wind Versus Ship Wind
(in knots)

	Winter	Spring	Summer	Fall
Mean 0000Z gradient wind	19.1	17.2	15.2	20.5
Mean 0000Z ship wind	15.0	13.2	11.2	14.3
% ship wind to 0000Z gradient wind	78%	77%	66%	70%
Mean 1200Z gradient wind	20.1	18.2	13.9	20.6
Mean 1200Z ship wind	14.1	12.6	10.9	14.2
% ship wind to 1200Z gradient wind	70%	70%	78%	69%
Standard deviation of ship wind using $w_s = .73w_g$	4.6	4.8	5.6	4.9

(Note: w_s is the ship wind, and w_g is the gradient wind.)

TABLE 3

Surface Wind Versus Gradient Wind by Quadrants
(in knots)

	NE	SE	SW	NW
Mean gradient wind	19.4	18.0	17.5	13.9
Mean ship wind	14.1	12.7	13.0	12.6
% ship wind to gradient wind	73%	71%	74%	91%
Mean gradient wind (day)	19.3	17.6	16.1	15.8
Mean land wind (day)	11.0	10.5	7.8	8.6
% land wind (day) to gradient wind	57%	60%	48%	54%
Mean gradient wind (night)	19.1	18.0	13.8	14.7
Mean land wind (night)	6.6	7.0	4.5	5.3
% land wind (night) to gradient wind	35%	39%	32%	36%

TABLE 4

Directional Wind Shear between Ship Wind and Gradient Wind
by Gradient Wind Speed (in degs)

	≤10	≤20	≤30	≤50
Winter	-12	10	10	8
Spring	8	8	8	19
Summer	3	4	8	5
Fall	20	9	7	11
Mean for year	5	8	8	11
Standard deviation of direction about mean	37	13	20	28

TABLE 5

Difference between Land and Ship Wind Directions (in degs)

	Day	Night
Winter	-9	13
Spring	-2	-10
Summer	5	-1
Fall	1	-7
Mean for year	-1	-1

TABLE 6

Variations in Observed Winds at AAFB, NAS, and FWC (in knots)

	AAFB	NAS	FWC
Average 0400LST	7.1	5.6	9.0
0800LST	7.8	6.8	9.5
1200LST	8.1	10.8	11.3
1600LST	7.3	9.2	10.1
2000LST	7.0	5.6	8.7
2400LST	7.4	5.2	8.6
Mean difference 1200LST - 2400LST	.7	5.6	2.7
Standard deviation of difference about mean	2.5	3.3	2.5

TABLE 7

Average Gust Factors

	AAFB	FWC	derived over water
kts 10-19	1.50	1.52	1.44